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ABSTRACT

This report provides results of Phase I of a project that researched the occupational area of instrumentation technology, established appropriate committees, and conducted task verification. These results are intended to guide development of a program designed to train instrumentation technicians. Section 1 contains general information: purpose of Phase I; description of the occupation, including nature of work, working conditions, and related occupations; direction of the occupation, including employment, training and other qualifications, advancement, job outlook, and earnings; program development committee; areas of concern; and State Technical Committee developmental recommendations. Section 2 presents research findings: accreditation and certification; list of typical job titles; and appropriate trade resources and sources, including references and textbooks, audiovisuals, curriculum materials, periodicals, safety manual, standards and recommended practices, test materials references, and sources of additional information. A verified occupational duty and task list is comprised of 27 duties, including AC and DC circuit theory application; matter; shop practices; safety; hand tools; blueprints, schematics, drawings; technical writing; electronic, hydraulic, pneumatic, and thermal test instruments; troubleshooting; and servicing equipment, systems, and measuring instruments. Other contents include staff and facilities recommendations. (YLB)

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# INSTRUMENTATION TECHNOLOGY

## PROJECT REPORT

## PHASE I

## WITH

## RESEARCH FINDINGS

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# INSTRUMENTATION TECHNOLOGY CONTRACT

## PROJECT REPORT

## PHASE I

## WITH

## RESEARCH FINDINGS

Developed by

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# SECTION ONE

# GENERAL INFORMATION

## Purpose of Phase I

Phase I focused on researching the occupation, establishing appropriate committees, and conducting task verification. The results of this phase have provided the basic information required to develop the program standards and guide and set up the committee structure to guide the project.

This program is designed to address the needs of the instrumentation technology field that use or plan to use graduates as instrumentation technicians.

## Description of Occupation

Nature of the Work

Engineering technicians use the principles and theories of science, engineering, and mathematics to solve problems in research and development, manufacturing, sales, and customer service. Their jobs are more limited in scope and more practically oriented than those of scientists and engineers. Many engineering technicians assist engineers and scientists, especially in research and development. Some technicians work on their own, servicing equipment at customers' worksites. Others work in production or inspection jobs.

Engineering technicians who work in research and development build or set up equipment, prepare experiments, calculate or record the results, and assist engineers in other ways. Some make prototype versions of newly designed equipment. They also assist in routine design work, often using computer-aided design equipment.

Engineering technicians who work in manufacturing follow the general directions of engineers. They may prepare specifications for materials, devise and run tests to ensure product quality, or study ways to improve manufacturing efficiency. They may also supervise production workers to make sure they follow prescribed procedures.

Engineering technicians also work as field representatives of manufacturers, wholesalers, or retailers. They help customers install, operate, and maintain complex technical equipment, and may write repair or operating manuals.

Electrical and electronics technicians develop, manufacture, and service equipment and systems such as radios, radar, sonar, television, industrial and medical measuring or control devices, navigational equipment, and computers, often using measuring and diagnostic devices to test, adjust, and repair equipment. Workers who only repair electronic equipment are discussed elsewhere in the Occupational Outlook Handbook under electrical electronic equipment repairers. These repairers are often incorrectly called electronics technicians.

Industrial engineering technicians study the efficient use of personnel, materials, and machines in factories, stores, repair shops, and offices. They prepare layouts of machinery and equipment, plan the flow of work, make statistical studies, and analyze production costs.

Mechanical engineering technicians work with engineers in design and development by making sketches and rough layouts of proposed machinery and other equipment and parts. In planning and testing experimental machines, they record data, make computations, plot graphs, analyze results, and write reports. When planning production, mechanical engineering technicians prepare layouts and drawings of the assembly process and of parts to be manufactured. They estimate labor costs, equipment life, and plant space. Some test and inspect machines and equipment in manufacturing departments or work with engineers to eliminate production problems.

Working Conditions

Most engineering technicians work regular hours in laboratories, offices, electronics shops, or industrial plants. Service representatives usually spend much of their time working in customers' establishments. Some may be exposed to electrical shock hazards from equipment.

Related Occupations

Engineering technicians apply scientific and engineering principles usually acquired in postsecondary programs below the baccalaureate level. Occupations of a similar nature include science technicians, drafters, surveyors, broadcast technicians, and health technologists and technicians.

## Direction of the Occupation

### Employment

Engineering technicians held about 689,000 jobs in 1986. Over two-fifths worked in manufacturing, mainly in the electrical and electronic machinery and equipment, transportation equipment, and machinery industries. Over one-fifth worked in service industries, mostly in engineering or business services companies who do engineering work on contract for government, manufacturing, or other organizations.

In 1986, the Federal Government employed about 64,000 engineering technicians. Almost two-fifths worked for the Department of Defense; others worked for the Departments of Transportation, Agriculture, and Interior, the Tennessee Valley Authority, and the National Aeronautics and Space Agency. State governments employed about 35,000 and local governments about 22,000.

### Training, Other Qualifications, and Advancement

Although persons can qualify for engineering technician jobs through many combinations of work experience and education, most employers prefer applicants with technical training. This training is available at technical institutes, junior and community colleges, extension divisions of colleges and universities, and public and private vocational-technical schools. Persons with college courses in science, engineering, and mathematics may also qualify for some positions, but may need additional specialized training and experience.

Training can also be obtained on the job or through apprenticeship programs or correspondence schools. Some types of Armed Forces training and experience also may qualify one for some engineering technician jobs.

Many types of publicly and privately operated schools provide technical training. The kind and quality of programs can vary considerably. Therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs obtained by graduates, instructional facilities and equipment, and faculty qualifications.

Technical institutes offer intensive technical training, but less theory and general education than junior and community colleges. Many offer 2-year associate degree programs, and are similar to or are part of a community college or state university systems. Other technical institutes are run by private, often for-profit, organizations, sometimes called proprietary school. Their programs vary considerably in length and types of courses offered. Some are 2-year associate degree programs.

Junior and community colleges offer curriculums similar to those in technical institutes but may include more theory and liberal arts. Often there may be little or no difference between technical institute and community college programs. However, courses taken at junior or community colleges are more likely to be accepted for credit at 4-year colleges than those at technical institutes. After completing the 2-year program, some graduates qualify for jobs as engineering technicians while others continue their education at 4-year colleges.

Training, Other Qualifications, and Advancement (cont.)

Four-year colleges usually do not offer engineering technician training, but college courses in science, engineering, and mathematics are useful for obtaining a job as an engineering technician.

Area vocational-technical schools are post-secondary public institutions that serve local students and emphasize training needed by local employers. Most require a high school diploma or its equivalent for admission.

Other training may be obtained in the Armed Forces in technical areas which can be applied in civilian engineering technician jobs. Some additional training may be needed, depending on the military skills acquired and the kind of job, but often this is gained on the job. Some correspondence schools also offer training for engineering technicians.

Prospective engineering technicians should take as many high school science and math courses as possible. Engineering technicians need an aptitude for mathematics and science. For design work, creativity also is desirable. They should be able to work well with others since they are often part of a team of engineers and other technicians. Those in sales and service should be able to work independently and deal effectively with customers.

Engineering technicians usually begin doing routine work under the close supervision of an experienced technician, engineer, or scientist. As they gain experience, they are given more difficult assignments with only general supervision. Some engineering technicians eventually become supervisors, and a few, engineers.

Job Outlook

Employment of engineering technicians is expected to increase much faster than the average for all occupations through the year 2000 due to anticipated increases in research and development expenditures and expected continued rapid growth in the output of technical products. Competitive pressures and advancing technology will force companies to improve and update manufacturing facilities and product designs more rapidly than in the past.

Despite the projected faster than average growth, most job openings will be to replace technicians who transfer to other occupations or leave the labor force.

Many technician jobs are defense related; cutbacks in defense spending could result in layoffs.

Earnings

Median annual earnings of full-time engineering technicians were about $24,000 in 1986; the middle 50 percent earned between $18,000 and $30,400. Ten percent earned less than $14,000, and 10 percent earned over $36,000.

In the Federal Government, engineering technicians could start at $11,802, $13,248, or $14,822 in 1987, depending on their education and experience.

The information presented in **Description of the Occupation** and **Direction of the Occupation** is adapted from public domain material, originally published in the *Occupational Outlook Handbook*, Bulletin 2300, by the Bureau of Labor Statistics, U.S. Department of Labor, Washington, DC 20212.

Instrumentation Technology

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## AREAS OF CONCERN

The State Technical Committee reached consensus that there is a shortage of job applicants:

a. having work habits and attitudes consistent with employment as instrumentation technicians;

b. having an adequate background in algebra, trigonometry, and physics.

c. competent in instrumentation operation, installation, and repair.

d. having adequate skill in analyzing and troubleshooting integrated instrumentation systems.

e. that understand the concept of and calibration procedures for the traceability of standards.

## STATE TECHNICAL COMMITTEE RECOMMENDATIONS

The State Technical Committee recommended that:

1. A diploma-level and a degree level program of study be developed.

2. The program developed should address the employment market needs for technicians in the instrumentation field.

3. The program content should include, but not be limited to:

   Basic instrumentation as applied to measurement and control.
   Principles of process control.
   Repair of instruments.
   Final report writing.
   Traceability the certification of standards.
   Calibration of instruments.
   Troubleshooting to board or component level as determined by system maintenance design.
   Configuration microprocessors to specific system requirements.
   Interpretation of technical materials

## SECTION TWO

## RESEARCH FINDINGS

## ACCREDITATION AND CERTIFICATION

There are no national or state requirements for program accreditation or certifitication established. There are no individual certification or licensure requirements which job applicants must meet prior to entry into occupation in the instrumentation field.

The Instrumentation Technology program must conform to the institutional accreditation requirements of the Southern Association of Colleges and Schools by meeting Commission on Colleges (COC) or Commission on Occupational Education Institutions (COEI) accreditation requirements and must not conflict with the accreditation criteria established by COC or COEI.

## TYPICAL JOB TITLES

Phase I research has included an examination of the occupational areas for the instrumentation technology field and has revealed three job titles for which training may be required. The *Dictionary of Occupational Titles* code and title are as follows:

| | |
|---|---|
| 003.261 - 010 | INSTRUMENTATION TECHNICIAN (profess. & kin.) |
| 710.281 - 026 | INSTRUMENT MECHANIC (any ind.) instrument-maintenance mechanic. |
| 710.281 - 030 | INSTRUMENT TECHNICIAN (light, heat, & power) oscillograph technician. |

## APPROPRIATE TRADE RESOURCES

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## APPROPRIATE TRADE RESOURCES

Audiovisuals

The following materials are available from:

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P.O. Box 238
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- Basic Electricity: DC Circuits
- Understanding Digital Electronics
- Basic Digital Math
- Multimeters Explained
- Using Dual Trace Oscilloscope
- Rotating Machinery: Magnetism
- Rotating Machinery: DC Generators and Motors
- Reading a Ruler
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- Electronic Power Supplies
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How to Read a Vernier Caliper
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The following materials are available from:

Instrument Society of America
P. O. Box 12277
Research Triangle Park, NC 27709
1-800-334-6391

Format: Videotapes (number of tapes)

Instrumentation (16)
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Safety in Electric Work
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Discovering Electricity - OUCH!
Basic Electronics
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Introduction to Electricity
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Components of AC Circuits
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Curriculum Materials

The following materials are available from:

Mid-America Vocational Curriculum Consortium
1500 West Seventh Avenue
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Introduction to Instrumentation, 1989
Process Instrumentation, 1989
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American Metric Journal Publishing Co.
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American National Standards Institute
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ASTM Standardization News
American Society for Testing and Materials
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Philadelphia, PA 19103

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National Conference of Standards Laboratories Newsletter
National Conference of Standards Laboratories
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Boulder, CO 80301

National Conference on Weights and Measures Report
U. S. National Bureau of Standards
Office of Weights and Measures
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9889 Willow Creek Road, Box 26875
San Diego, CA 92126

## APPROPRIATE TRADE RESOURCES

Safety Manual

Bartsch, John H. (1987). *School Materials Safety Manual.* Schenectady, NY: Genium.

Standards and Recommended Practices

Following are titles for "focused standards" available from:

Instrument Society of America
P. O. Box 12277
Research Triangle Park, NC 27709
1-800-334-6391

Symbols, Diagrams, & Identification
Instrumentation Installed in Hazardous Locations
Combustible Gas Detection
Face-to-Face Dimensions for Control Valves
Safety Standards for Electrical and Electronic Test, Measurement, Controlling, & Related Equipment

For individual issues are also available from ISA.

## APPROPRIATE TRADE RESOURCES

Test Materials References

Lewis, M. V. & Martin, S. C. (1986). *Measures of occupationally specific and nonoccupational specific knowledge and skills: A compendium*. Columbus, OH: The National Centre for Research in Vocational Education, The Ohio State Univeristy.

Norton, R. E., & Others. (1988). *Competency-based testing for occupational students: A resource guide*. Athens, GA: American Association for Vocational Instructional Materials.

Competency-Based Testing Materials

Source: American Association for Vocational Instructional Materials (AAVIM)
120 Driftmier Engineering Center
Athens, GA 30602

Area: Electronics Technician

Source: Kentucky Department of Education
Office of Vocational Education
Curriculum Development Unit
2028 Capital Plaza Tower
Frankfort, Kentucky 40601
(502) 564-2890

Area: Electronics Technician

Source: National Occupational Competency Testing Institute (NOCTI)
Ferris State College
318 Johnson Hall
Big Rapids, Michigan 49307
(616) 796-4695

Area: Electromechanical Technology, Electronics Technology

## APPROPRIATE TRADE RESOURCES

National Network for Curriculum Coordination
in Vocational & Technical Education

For information on postsecondary materials contact:

Ms. Patt Stonehouse, Acting
Director of Instructional Services
Georgia Department of Technical
and Adult Education
Suite 660 South Tower
One CNN Center
Atlanta, GA 30303-2705
404-656-6714

## APPROPRIATE TRADE RESOURCES

Sources of Additional Information

For information on a career as an instrumentation technician contact:

Director, Labor Information Systems
Georgia Department of Labor
254 Washington Street, SW
Atlanta, GA 30334
404-656-3177

Executive Director, Georgia Occupational Information
Coordinating Committee
142 Marietta Street, NE
Atlanta, GA 30303
404-656-3177

VERIFIED INSTRUMENTATION TECHNOLOGY TASK LIST

DUTY A: APPLY DC CIRCUITY THEORY

A01 Solve basic algebraic problems as applicable to electronics.
A02 Relate electricity to nature of matter.
A03 Identify sources of electricity.
A04 Define voltage, current, resistance, power, and energy.
A05 Apply and relate Ohm's law.
A06 Read and interpret color codes to identify resistors.
A07 Measure properties of a circuit using VOM and DVM meters.
A08 Compute and measure conductance and resistance of conductors and insulators.
A09 Analyze series circuits.
A10 Construct series circuits.
A11 Troubleshoot series circuits.
A12 Analyze parallel circuits.
A13 Construct parallel circuits.
A14 Troubleshoot parallel circuits.
A15 Analyze series-parallel circuits.
A16 Construct series-parallel circuits.
A17 Troubleshoot series-parallel circuits.
A18 Analyze voltage dividers (loaded and unloaded).
A19 Construct voltage dividers (loaded and unloaded).
A20 Troubleshoot voltage dividers (loaded and unloaded).
A21 **DROPPED** Solve network theorem problems.
A22 **DROPPED** Analyze maximum power transfer theory.
A23 **DROPPED** Construct maximum power transfer theory.
A24 **DROPPED** Troubleshoot maximum power transfer theory.
A25 Define magnetic properties of circuits and devices.
A26 Determine physical and electrical characteristics of capacitors and inductors.
A27 Analyze and measure RL and RC time constants.
A28 Set up and operate VOM for DC circuits.
A29 Set up and operate DVM for DC circuits.
A30 Set up and operate power supplies for DC circuits.
A31 Set up and operate oscilloscopes for DC circuits.

DUTY B: APPLY AC CIRCUIT THEORY

B01 Solve basic trigonometric problems as applicable to electronics.
B02 Identify properties of an AC signal.
B03 Identify AC sources.
B04 Analyze and measure AC signals using oscilloscopes, frequency meters, and generators.
B05 Analyze AC capacitive circuits.
B06 **DROPPED** Construct AC capacitive circuits.
B07 Troubleshoot AC capacitive circuits.
B08 Analyze AC inductive circuits.
B09 **DROPPED** Construct AC inductive circuits.
B10 Troubleshoot AC inductive circuits.
B11 Analyze and apply principles of transformers to AC circuits.
B12 Analyze RLC circuits (series, parallel, complex).
B13 **DROPPED** Construct RLC circuits (series, parallel, complex).

B14 Troubleshoot RLC circuits (series, parallel, complex).
B15 Analyze series and parallel resonant circuits.
B16 **DROPPED** Construct series and parallel resonant circuits.
B17 Troubleshoot series and parallel resonant circuits. .
B18 Analyze filter circuits.
B19 **DROPPED** Construct filter circuits.
B20 Troubleshoot filter circuits.
B21 **DROPPED** Analyze polyphase circuits.
B22 **DROPPED** Construct polyphase circuits.
B23 **DROPPED** Troubleshoot polyphase circuits.
B24 Analyze basic motor theory and operation.
B25 Analyze basic generator theory and operation.
B26 Set up and operate VOM for AC circuits.
B27 Set up and operate DVM for AC circuits.
B28 Set up and operate power supplies for AC circuits.

DUTY C: IDENTIFY THE PHYSICAL PROPERTIES OF STATES OF MATTER
C01 Identify the physical properties of gases.
C02 Identify the physical properties of liquids.
C03 Identify the physical properties of solids.
C04 Identify the nature of force.
C05 Identify the physical properties of motion.
C06 Identify the principles of work and energy.
C07 Identify the principles of simple machines.
C08 Calculate areas and volume.

DUTY D: APPLY PROPER SHOP PRACTICES
D01 Apply proper safety standards.
D02 Make electrical connections.
D03 Handle static sensitive devices.
D04 Identify and use fasteners (screws, washers, pins, connectors).
D05 Solder using proper soldering techniques.
D06 Set up and operate scales.
D07 Set up and operate micrometers.
D08 Set up and operate rulers.
D09 Set up and operate **GAUGE** blocks. (BOLD INDICATES CHANGE)
D10 Set up and operate dial indicators.
D11 Set up and operate Vernier scales.
D12 Set up and operate mechanical and optical measuring devices.
D13 Set up and operate height gauges.
D14 Set up and operate depth gauges.
D15 Read and convert measurements.
D16 Perform preventive maintenance according to vendor specifications.

DUTY E: IDENTIFY SAFE WORK PROCEDURES
E01 Identify plant safety procedures.
E02 Observe safety precautions for tools and equipment.
E03 Identify machinery safeguards.
E04 Observe safety in handling materials.

E05 Identify work area safety precautions.
E06 Identify fire prevention procedures.
E07 Observe safety in handling hazardous materials.
E08 Observe electrical safety precautions.
E09 Identify personal protection gear.

DUTY F: SELECT AND USE HAND TOOLS
F01 Select and use hand tools.
F02 Select and use power tools.
F03 Select types of fasteners.
F04 Select and use wrenches and screwdrivers.
F05 **ELECTIVE COURSE** Select and use pipefitting tools.
F06 **ELECTIVE COURSE** Select plumbing tools.
F07 **ELECTIVE COURSE** Utilize plumbing tools.
F08 **ELECTIVE COURSE** Select and use sheet metal tools.
F09 **ELECTIVE COURSE** Select and use metal working tools.
F10 **ELECTIVE COURSE** Select and use hoisting and pulling tools.

DUTY G: INTERPRET BLUEPRINTS, SCHEMATICS AND DRAWINGS
G01 Identify basic principles of blueprint reading.
G02 Identify elements of machine drawings.
G03 Identify hydraulic and pneumatic drawings.
G04 Read and interpret blueprint drawings.
G05 Read and interpret electrical drawings.
G06 **ELECTIVE COURSE** Read and interpret pipe system drawings.
G07 **ELECTIVE COURSE** Read and interpret sheet metal drawings.
G08 Apply shop math to interpret blueprints.
schematic diagrams.
G09 Sketch schematic diagrams.
G10 Identify types of schematics used in plant engineering.
G11 Identify the symbols on electrical, piping, fluid power, and pneumatic diagrams.
G12 Identify guidelines for reading schematics.
G13 Identify electrical symbols.
G14 Read and interpret electrical diagrams.
G15 **NESTED IN G11** Identify piping symbols.
G16 Read and interpret piping schematics.
G17 **NESTED IN G11** Identify fluid power symbols.
G18 Read and interpret fluid power schematics.
G19 **DROPPED** Identify welding symbols.
G20 Draw electrical one-line diagrams from engineering sketches.
G21 Draw electrical elementary diagrams from engineering sketches.
G22 Draw electronic schematic diagrams from engineering sketches.
G23 Prepare preliminary sketches.
G24 Draw logic symbols.
G25 Read and interpret Instrument Society of America (ISA) instrumentation symbols and identifications.
G26 Read and interpret instrument loop drawings.
G27 Read and interpret piping and instrument drawings.
G28 Read and interpret logic diagrams.

G29 Read and interpret ladder diagrams.
G30 Read and interpret pneumatic systems schematics.

DUTY H: MAINTAIN TECHNICAL RECORDS AND WRITE TECHNICAL REPORTS

H01 Draw and interpret electrical, electronic, and mechanical schematics.
H02 Record data and design curves and graphs.
H03 Write reports.
H04 Maintain test logs.
H05 Make equipment failure reports.
H06 Specify and requisition simple electronic components.
H07 **DROPPED** Compose technical letters.
H08 Write formal reports of laboratory experiments.
H09 Record instrument calibration data.

DUTY I: SELECT AND OPERATE ELECTRONIC TEST INSTRUMENTS

I01 Select and operate basic measuring instruments.
I02 Select and operate volt-OHM milliammeters (VOM).
I03 Perform condition test on volt-OHM milliammeters (VOM).
I04 Select and operate electronic voltmeter (EVM).
I05 Perform condition test on electronic voltmeter (EVM).
I06 Select and operate Ohmeters.
I07 Select and operate oscilloscopes.
I08 **NESTED IN I07** Perform condition test on oscilloscopes.
I09 **NESTED IN I07** Select and operate tube testers.
I10 **NESTED IN I07** Perform condition test on tube testers.
I11 **NESTED IN I07** Select and operate transistors analyzers.
I12 **NESTED IN I07** Perform condition test on transistor analyzers.
I13 Select and operate capacitor testers.
I14 **NESTED IN I13** Perform condition test on capacitor testers.
I15 **NESTED IN I17** Select and operate sine wave generators.
I16 **NESTED IN I17** Perform condition test on sine wave generators.
I17 Select and operate signal generators.
I18 **NESTED IN I17** Select and operate pulse generators.
I19 **NESTED IN I17** Perform condition test on pulse generators.
I20 **NESTED IN I17** Select and operate square wave generators.
I21 **NESTED IN I17**Perform condition test on square wave generators.
I22 Select and operate impedance testers.
I23 Select and operate frequency meters.
I24 Perform condition test on frequency meters.
I25 **DUPLICATE** Operate test instruments to measure voltage, current and resistance.
I26 Select and operate decade boxes.
I27 **DROPPED** Perform condition test on resistor substitution boxes.
I28 Select and operate Wheatstone bridges.
I29 Select and operate ph instruments.
I30 Select and operate conductivity measuring instruments.
I31 Select and operate millivolt sources.
I32 Select and operate milliamp sources.

DUTY J: SELECT AND OPERATE HYDRAULIC TEST INSTRUMENTS

J01 Select and operate basic hydraulic instruments.
J02 Select and operate dead weight testers.
J03 Select and operate manometers.
J04 Select and operate pressure gauges.

DUTY K: SELECT AND OPERATE PNEUMATIC TEST INSTRUMENTS
K01 Select and operate basic pneumatic measuring instruments.
K02 Select and operate pressure calibrators.
K03 Select and operate vacuum pumps.
K04 Select and operate dead weight testers.
K05 Select and operate manometer.
K06 Select and operate pressure and vacuum gauges.

DUTY L: SELECT AND OPERATE THERMAL TEST INSTRUMENTS
L01 Select and operate basic thermal measuring Instruments.
L02 Select and operate heat baths.
L03 Select and operate potentiometers.
L04 Select and operate thermometers.

DUTY M: MEASURE AND MAINTAIN DC VOLTAGE AND AC LOW AND HIGH FREQUENCY
M01 Determine meter movement, sensitivity, and resistance.
M02 Extend the current range of a meter movement.
M03 Extend the voltage range of a meter movement.
M04 Perform condition test of semiconductor diodes using Ohmeter.
M05 Test amplifiers for amplification.
M06 **NESTED IN M09** Determine vacuum tube amplifier failures.
M07 Troubleshoot **OPERATIONAL** amplifiers.
M08 Remove and replace **OPERATIONAL** amplifier components.
M09 Perform operational systems checks **ON OPERATIONAL** amplifiers.
M10 **NESTED IN M13** Determine transistor amplifier failures.
M11 Troubleshoot transistor amplifiers.
M12 Remove and replace transistors amplifier components.
M13 Perform operational systems checks **ON** transistor amplifiers.
M14 Identify component parts and electrical characteristics of power supply circuits.
M15 **NESTED IN M18** Determine power supplies.
M16 Troubleshoot power supplies.
M17 Remove and replace power supply components.
M18 Perform operational systems checks to power supplies. **MODIFIED**
M19 **ADJUST OSCILLATORS . (DROPPED** Determine oscillator failures.)
M20 Troubleshoot oscillators.
M21 Remove and replace oscillator components.
M22 Perform operating systems checks to oscillators. **MODIFIED**
M23 **ADJUST CLAMPERS. (DROPPED** Determine clamper failures.)
M24 Troubleshoot clampers.
M25 Remove and replace clamper components.
M26 Perform operating systems checks to clampers. **MODIFIED**
M27 **ADJUST CLIPPERS. (DROPPED** Determine clipper failures.)
M28 Troubleshoot clipper circuits.

M29 Remove and replace clipper circuit components.
M30 Perform operating systems checks to clipper circuits. **MODIFIED**
M31 **ADJUSR COUNTERS. (DROPPED** Determine counter failures.)
M32 Troubleshoot counters.
M33 Remove and replace counter components.
M34 Perform operating systems checks to counters. **MODIFIED**
M35 **DROPPED** Construct and perform condition tests of oscillators.
M36 **DROPPED** Construct and perform condition tests of pulse circuits.
M37 **DROPPED** Determine nonsinusoidal amplifier failures.
M38 **DROPPED** Troubleshoot nonsinusoidal amplifiers.
M39 **DROPPED** Remove and replace nonsinusoidal amplifier components.
M40 **DROPPED** Perform operating systems checks and make minor adjustments to nonsinusoldal amplifiers.
M41 **DROPPED** Determine sweep-generator circuit failures.
M42 **DROPPED** Troubleshoot sweep-generator circuits.
M43 **DROPPED** Remove and replace sweep-generator circuits.
M44 **DROPPED** Perform operating systems checks and make minor adjustments to sweep generator circuits.

DUTY N: INSTALL ELECTRICAL SYSTEM COMPONENTS
N01 Identify the basic principles and terminology of process control systems.
N02 Identify components of process control systems.
N03 Create block diagrams of simple and complex loops.
N04 Identify manual settings on process control systems.
N05 Identify set point controllers on automatic process controls.
N06 Identify on-off controllers on automatic process controls.
N07 Identify proportional controllers on automatic process controls.
N08 Identify proportional-integral controllers on automatic process controls
N09 Identify proportional-integral-derivative controllers on automatic process controls.
N10 Identify final control elements on automatic process controls.
N11 Identify practical applications of power.
N12 Identify electrical principles.
N13 Identify electrical motors.
N14 Read and interpret electrical schematic diagrams.
N15 Install electrical system components.
N16 Identify procedures for electrical system maintenance.
N17 Determine electrical system failures.
N18 Troubleshoot electrical systems using diagnostic techniques.
N19 Remove and replace electrical system components.
N20 Perform operating systems checks and make minor adjustments to electrical systems.
N21 Identify system interfaces.

DUTY O: IDENTIFY, ADJUST, AND TROUBLESHOOT HYDRAULIC AND PNEUMATIC SYSTEMS
O01 Identify practical applications of hydraulic power.
O02 Identify hydraulic principles.
O03 Identify control valves.
O04 Identify pressure and safety relief valves and vacuum breakers.
O05 Identify cylinders.

O06 Identify motors.
O07 Read and interpret hydraulic schematic drawings.
O08 Install hydraulic system components.
O09 Identify procedures for hydraulic system maintenance.
O10 Determine hydraulic system failures.
O11 Troubleshoot hydraulic system using diagnostic techniques.
O12 Remove and replace hydraulic system.
O13 Perform operating systems checks and make minor adjustment to hydraulic systems.
O14 Identify strainers and filters in hydraulic systems.
O15 Identify reservoirs and accumulators in hydraulic systems.
O16 Identify hydraulic pumps on a system.
O17 Identify piping, tubing, and fittings on a hydraulic system.
O18 Identify directional control valves in hydraulic systems.
O19 Identify hydraulic fluid.
O20 Identify hydraulic system interfaces.
O21 Identify practical applications of pneumatic power.
O22 Identify pneumatic principles.
O23 Identify reciprocating compressors.
O24 Identify rotary compressors.
O25 Identify primary air treatment in pneumatic systems.
O26 Identify secondary air treatment methods.
O27 Identify piping, hoses, and fittings used in pneumatic systems.
O28 Identify relief and safety valves and vacuum breakers used in#pneumatic systems.
O29 Identify control valves used in pneumatic systems.
O30 Identify cylinders used in pneumatic systems.
O31 Identify motors used in pneumatic systems.
O32 Identify components of pneumatic systems.
O33 Read and interpret schematic diagrams.
O34 Identify the procedures for pneumatic system maintenance.
O35 Determine pneumatic system failures.
O36 Troubleshoot pneumatic systems.
O37 Remove and replace pneumatic system components.
O38 Perform operating systems checks and make minor adjustments to pneumatic systems.
O39 **DROPPED** Determine air compressor failures.
O40 **DROPPED** Troubleshoot air compressor.
O41 **DROPPED** Remove and replace air compressor components.
O42 Perform operating systems checks and make minor adjustments to pneumatic systems.
O43 **ADJUST CONTROL VALVES (DROPPED** Determine control valve failures.)
O44 Troubleshoot control valves **AND ACTUATORS.**
O45 Remove and replace control valve **AND ACTUATOR** components.
O46 Perform operating systems checks to control valves **AND ACTUATORS. MODIFIED**
O47 **ADJUST DIAPHRAGM. (DROPPED** Determine cylinder failures.)
O48 Troubleshoot **DIAPHRAGM. (MODIFIED)**
O49 Remove and replace **DIAPHRAGM** components.**(MODIFIED)**
O50 Perform operating systems checks to **DIAPHRAGM. (MODIFIED)**
O51 **ADJUST PNEUMATIC OPERATORS. (DROPPED** Determine air motor failures.)
O52 Troubleshoot **PNEUMATIC OPERATORS. (MODIFIED)**
O53 Remove and replace **PNEUMATIC OPERATOR** components.**(MODIFIED)**
O54 Perform operating systems checks to **PNEUMATIC OPERATORS. (MODIFIED)**

O55 Identify strainers and filters in pneumatic systems.
O56 Identify reservoirs in pneumatic systems.
O57 Identify pneumatic pumps on systems.
O58 Identify directional control valves on pneumatic systems.
O59 Identify pneumatic system interfaces.

DUTY P: SERVICE ELECTRONIC EQUIPMENT

P01 Perform visual inspection on electronic equipment.
P02 Clean electronic equipment.
P03 Lubricate electronic equipment.
P04 Inspect and replace power cords and distribution cables.
P05 Inspect and replace resistors.
P06 Inspect and replace capacitors.
P07 Inspect and replace inductors.
P08 Inspect and replace vacuum tubes.
P09 Inspect and replace transistors.
P10 Inspect and replace IC units.
P11 Inspect and replace printed circuit (PC) boards.
P12 Perform a proof of performance check on electronic equipment.
P13 Keep records on maintenance of equipment.

DUTY Q: SERVICE INSTRUMENT SYSTEMS

Q01 Identify automatic control systems functions.
Q02 Identify the elements of process control.
Q03 Identify system transmitters and receivers.
Q04 Identify diagram symbols and networks.
Q05 Identify parameters of an operational process control system.
Q06 Identify measurement purpose and requirements.
Q07 Identify the elements of measurement systems.
Q08 Identify measured transducers.
Q09 Identify instrument calibration standard units.
Q10 Analyze systems using troubleshooting flow sheet.
Q11 Identify pressure principles.
Q12 Identify pressure sensors.
Q13 Identify pressure transducers.
Q14 Identify low pressure measurement gauges requirements.
Q15 Install and service pressure instruments.
Q16 Identify force, stress, and strain measurement units.
Q17 Identify weight and mass measuring instruments.
Q18 Identify methods for weighing materials in motion.
Q19 Identify displacement measurement methods.
Q20 Identify acceleration vibration, and shock measurement methods.
Q21 Identify the properties of fluid flow measurement.
Q22 Identify primary measuring devices for fluid flow.
Q23 Identify secondary measuring devices for fluid flow.
Q24 Identify applications for variable area instruments.
Q25 Identify open channel flow devices.
Q26 Identify applications for positive displacement meters.
Q27 Identify applications for turbine flow meters

Q28 Identify applications magnetic flow meters.
Q29 Identify applications for ultrasonic flow metering methods.
Q30 Identify solid particles flow metering methods.
Q31 Install and maintain flow instruments.
Q32 Identify level measurement instruments.
Q33 Identify pressure head instruments.
Q34 Identify electrical methods for level measurement.
Q35 Identify solid level measuring systems.
Q36 Service level measuring instruments.
Q37 Identify temperature measuring principles and sensors.
Q38 Identify bimetallic and fluid-filled temperature measuring instrument.
Q39 Identify instruments using electrical methods of measuring temperature.
Q40 Identify pyrometers.
Q41 Perform temperature measuring instrument maintenance.
Q42 Identify final control elements in process loops.
Q43 Identify electric actuators.
Q44 Identify pneumatic and hydraulic actuators.
Q45 Identify control valves.
Q46 Identify control element applications.
Q47 Identify on-site safety standards and maintenance practices.
Q48 Identify servicing requirements.
Q49 Detail electrical and electronic servicing stations.'
Q50 Detail pneumatic and hydraulic servicing stations.
Q51 Detail troubleshooting requirements.
Q52 Identify applications of vacuum measuring methods.

DUTY R: TROUBLESHOOT AND SERVICE THERMAL MEASURING
R01 Determine temperature measuring instrument and sensor failures.
R02 Troubleshoot temperature measuring instruments and sensors.
R03 Remove and replace temperature measuring instrument and sensor components.
R04 Perform operating systems checks and make adjustments to temperature measuring instruments and sensors.
R05 Determine calorific value measuring instrument failures.
R06 Troubleshoot calorific value measuring instrument.
R07 Remove and replace calorific value measuring instrument components.
R08 Perform operating systems checks and make minor adjustments to calorific value measuring instruments.

DUTY S: TROUBLESHOOT AND SERVICE RADIATION MEASURING INSTRUMENTS
S01 Determine radiation measuring instrument failures.
S02 Troubleshoot radiation measuring instruments.
S03 Remove and replace radiation measuring instrument components.
S04 Perform operating systems checks and make minor adjustments to radiation measuring instruments.
S05 Determine photometric measuring instrument failures.
S06 Troubleshoot photometric measuring instruments.
S07 Remove and replace photometric measuring instrument components.
S08 Perform operating systems checks and make minor adjustments to photometric

measuring instruments.
S09 Determine acoustic measuring instrument failures.
S10 Troubleshoot acoustic measuring instruments.
S11 Remove and replace acoustic measuring instrument components.
S12 Perform operating systems checks and make minor adjustments to acoustic measuring instruments.

DUTY T: TROUBLESHOOT AND SERVICE FORCE MEASURING INSTRUMENTS
T01 Identify force measuring instruments.
T02 Determine moment (torque) measuring instrument failures.
T03 Troubleshoot moment (torque) measuring instruments.
T04 Remove and replace moment (torque) measuring instrument components.
T05 Perform operating systems checks and make adjustments to moment (torque) meas: instruments.
T06 Determine force per unit area measuring instrument failures.
T07 Troubleshoot force per unit area measuring instruments.
T08 Remove and replace force per unit area measuring instrument components.
T09 Perform operating systems checks and make adjustments to force per unit area me instruments.

DUTY U: TROUBLESHOOT AND SERVICE RATE MEASURING INSTRUMENTS
U01 Determine flow measuring instrument failures.
U02 Troubleshoot flow measuring instrument failures.
U03 Remove and replace flow measuring instrument components.
U04 Perform operating systems checks and make minor adjustments to flow measuring instruments.
U05 Determine speed measuring instrument failures.
U06 Troubleshoot speed measuring instruments.
U07 Remove and replace speed measuring instrument components.
U08 Perform operating systems check and make minor adjustments to speed measuring instruments.
U09 Determine velocity measuring instrument failures.
U10 Troubleshoot velocity measuring instruments.
U11 Remove and replace velocity measuring instrument components.
U12 Perform operating systems checks and make minor adjustments to velocity measuring instruments.
U13 Determine acceleration measuring instrument failures.
U14 Troubleshoot acceleration measuring instruments.
U15 Remove and replace acceleration measuring instrument components.
U16 Perform operating systems checks and make minor adjustments #o acceleration measuring instruments.

DUTY V: TROUBLESHOOT AND SERVICE QUANTITY MEASURING INSTRUMENTS
V01 Determine mass measuring instrument failures.
V02 Troubleshoot mass measuring instrument failures.
V03 Remove and replace mass measuring instrument components.
V04 Perform operating systems checks and make minor adjustments to mass measuring

instruments.

V05 Determine weight measuring instrument failures.
V06 Troubleshoot weight measuring instruments.
V07 Remove and replace weight measuring instrument components.
V08 Perform operating systems checks and make minor adjustments to weight measuring instruments.

DUTY W: TROUBLESHOOT AND SERVICE PHYSICAL PROPERTY MEASURING INSTRUMENTS

W01 Determine density and specific gravity measuring instruments failures.
W02 Troubleshoot density and specific gravity measuring instruments.
W03 Remove and replace density and specific gravity measuring instrument components.
W04 Perform operating systems checks and make adjustments to density and specific gravity measuring instruments.
W05 Determine humidity measuring instrument failures.
W06 Troubleshoot humidity measuring instruments.
W07 Remove and replace humidity measuring instrument components.
W08 Perform operating systems checks and make minor adjustments to humidity measuring instruments.
W09 Determine moisture content measuring instrument failures.
W10 Troubleshoot moisture content measuring instruments.
W11 Remove and replace moisture content measuring instrument components.
W12 Perform operating systems checks and make minor adjustments to molsture content measuring instruments.
W13 Determine viscosity measuring instrument failures.
W14 Troubleshoot viscosity measuring instruments.
W15 Remove and replace viscosity measuring instrument components.
W16 Perform operating systems checks and make minor adjustments to viscosity measuring instruments.
W17 Determine consistency measuring instrument failures.
W18 Troubleshoot consistency measuring instruments.
W19 Remove and replace consistency measuring instrument components.
W20 Perform operating systems check and make minor adjustments to consistency measuring instruments.
W21 Determine structural characteristics measuring instrument failure.
W22 Troubleshoot structural characteristic measuring instruments.
W23 Remove and replace structural characteristic measuring instrument components.
W24 Perform operating systems checks and make adjustments to structural characteristic measuring instruments.

DUTY X: TROUBLESHOOT AND SERVICE CHEMICAL PROPERTY MEASURING INSTRUMENTS

X01 Determine analytical measuring instrument failures.
X02 Troubleshoot analytical measuring instruments.
X03 Remove and replace analytical measuring instrument components.
X04 Perform operating systems checks and make minor adjustments to analytical measuring instruments.
X05 Determine pH measuring instrument failures.
X06 Troubleshoot pH measuring instruments.

X07 Remove and replace pH measuring instrument components.
X08 Perform operating systems checks and make minor adjustments to pH measuring instruments.
X09 Determine liquid conductivity measuring instrument failures.
X10 Troubleshoot liquid conductivity measuring instruments.
X11 Remove and replace liquid conductivity measuring instrument components.
X12 Perform operating systems checks and make adjustments to liquid conductivity measuring instruments.
X13 Determine chromatograph measuring instrument failures.
X14 Troubleshoot chromatograph measuring instruments.
X15 Remove and replace chromatograph measuring instrument components.
X16 Perform operating systems check and make minor adjustments to chromatograph measuring instruments.
X17 Determine mass spectrometer measuring instrument failures.
X18 Troubleshoot mass spectrometer measuring instruments.
X19 Remove and replace mass spectrometer measuring instrument components.
X20 Perform operating systems checks and make adjustments to mass spectrometer measuring instruments.
X21 Determine gas analyzer measuring instrument failures.
X22 Troubleshoot gas analyzer measuring instruments.
X23 Remove and replace gas analyzer measuring instruments.
X24 Perform operating systems checks and make minor adjustments to ga analyzer measuring instruments.

DUTY Y: TROUBLESHOOT AND SERVICE ELECTRICAL MEASURING INSTRUMENTS

Y01 Determine electromotive force measuring instrument failures.
Y02 Troubleshoot electromotive force measuring instruments.
Y03 Remove and replace electromotive force measuring instrument components.
Y04 Perform operating systems checks and make adjustments to electromotive force measuring instruments.
Y05 Determine electric current measuring instrument failures.
Y06 Troubleshoot electric current measuring instruments.
Y07 Remove and replace electric current measuring instrument components.
Y08 Perform operating systems checks and make adjustments to electric current measuring instruments.
Y09 Determine resistance measuring instrument failures.
Y10 Troubleshoot resistance measuring instruments.
Y11 Remove and replace resistance measuring instrument components.
Y12 Perform operating systems checks and make minor adjustments to resistance measuring instruments.
Y13 Determine conductance measuring instrument failures.
Y14 Troubleshoot conductance measuring instruments.
Y15 Remove and replace conductance measuring instrument components.
Y16 Perform operating systems checks and make minor adjustments to conductance measuring instruments.
Y17 Determine inductance measuring instrument failures.
Y18 Troubleshoot inductance measuring instruments.
Y19 Remove and replace inductance measuring instruments components.

Y20 Perform operating systems checks and make minor adjustments to inductance measuring instruments.
Y21 Determine capacitance measuring instrument failures..
Y22 Troubleshoot capacitance measuring instruments.
Y23 Remove and replace capacitance measuring instrument components.
Y24 Perform operating systems checks and make minor adjustments to capacitive measure instruments.
Y25 Determine impedance measuring instrument failures.
Y26 Troubleshoot impedance measuring instruments.
Y27 Remove and replace impedance measuring instrument components.
Y28 Perform operating systems checks and make minor adjustments to impedance measuring instruments.

DUTY Z: CALIBRATE TEST INSTRUMENTS
Z01 Calibrate volt-OHM milliammeters (VOM).
Z02 Calibrate electronic voltmeters (EVM).
Z03 Calibrate tube testers.
Z04 Calibrate transistor testers.
Z05 Calibrate resistor substitution boxes.
Z06 Calibrate oscilloscopes.
Z07 Calibrate sine wave generators.
Z08 Calibrate square wave and pulse generators.
Z09 Calibrate frequency meters.
Z10 Calibrate power supply voltage.

DUTY AA: DEMONSTRATE AND PRACTICE EMPLOYABILITY SKILLS
AA01 List sources of job opening other than public or private employment agencies.
AA02 Write a letter of application for a job.
AA03 Prepare a vita, resume or personal fact sheet.
AA04 List factors to consider when applying for a job.
AA05 List ways of making contact with employers.
AA06 Identify documents which may be required#hen applying for a job interview.
AA07 Complete a job application form correctly.
AA08 Identify appropriate dress and grooming for a job interview.
AA09 Classify behaviors considered appropriate or inappropriate in a job interview situation.
AA10 Describe advantage to employer and employees of being a productive worker.
AA11 Explain the purpose of supervision, self discipline and performance evaluation.
AA12 Identify appropriate response(s) to criticism from employer, supervisor or other employees.
AA13 List consequences of being absent frequently from the job.
AA14 List consequences of frequently arriving late for work.
AA15 List factors to consider when resigning from a job.
AA16 Write a letter of resignation.

## TOOLS AND EQUIPMENT

The tools and equipment for the Instrumentation Technology Program will be determined in the next phase of development.

## STAFF

It is anticipated that the program standards and the program guide developed as a result of this project will not change present staffing levels and certification requirements.

## FACILITIES

The State Technical Committee members recommended that facilities be maintained in accordance with or exceed industry standards for the instrumentation technology field and those established in the Institutional Standards and General Program Standards.

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